U. S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Selenium in the Ecosystem of the Grassland Area of the San Joaquin Valley: Has the Problem Been Fixed?

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By

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Selenium in the Ecosystem of the Grassland Area of the San Joaquin Valley: Has the Problem Been Fixed?

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Abstract: The West Grassland area consists of 26,690 hectares of federal, state, and private native pasture and seasonal wetlands representing the largest tract of waterfowl habitat in the San Joaquin Valley of California. Subsurface tile drains, designed to remove saline water from the root zone of agricultural crops, have been installed in irrigated farmland of the western San Joaquin Valley since 1960. Although subsurface drainage water contains elevated concentrations of selenium as well as other naturally occurring trace elements and salts, it was used for wetland management for several decades. In the early 1980s it was discovered that selenium in the drainwater caused malformations and reproductive failure in waterfowl at the Kesterson National Wildlife Refuge. Selenium levels in waterfowl tissue were also high enough to warrant the issuance of human health advisories. Beginning in 1985, agricultural drainwater was no longer applied directly to wetlands, but wetland water supply channels continued to be used periodically to convey agricultural drainwater through wetland areas to the San Joaquin River. Since September of 1996 a new drainwater management program, the Grassland Bypass Project (GBP), has been diverting the agricultural drainwater through the San Luis Drain, thus removing drainwater from Grassland area channels that are used to supply wetlands. The purpose of this project is to provide a timely assessment of the degree to which drainwater management initiatives have indeed reduced toxicological risk to wildlife in the area. Selenium levels in most bird eggs (93.5%) were below the 6.0 µg/g level of concern. Somewhat elevated selenium concentrations in fish, tadpole, and invertebrate samples collected mainly from ditches and canals indicate that the selenium problem in the South Grassland area has improved but remains unresolved. Full recovery of the Grassland area wetland ecosystems may not yet be fully realized for two potential reasons: (A) recycling of a persistent reservoir of residual selenium, and (B) continuing input of additional selenium into the ecosystems.

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INTRODUCTION

The West Grasslands lies within the 20,655 ha Grassland Water District (GWD) and consists of 19,035 ha of private waterfowl hunting clubs in Merced County, California west of the San Joaquin River and between the towns of Gustine and Dos Palos (U.S. Fish and Wildlife Service, 1978). Together with 7,655 ha of federal refuge and state wildlife area lands, this 26,690 ha area of native pasture and seasonal wetlands represents the largest tract of waterfowl habitat in the San Joaquin Valley (Gilmer et al. 1982, Grassland Water District and Grassland Water Task Force 1986). The West Grasslands is further subdivided into the North Grasslands (north of the city of Los Banos) and the South Grasslands (south of Los Banos).

Subsurface tile drains, designed to remove saline water from the root zone of agricultural crops, have been installed in irrigated farmland of the western San Joaquin Valley of California since 1960 (U.S. Bureau of Reclamation 1984). Although subsurface drainage water contains elevated concentrations of selenium as well as other naturally occurring trace elements and salts (Presser and Barnes 1985, Presser and Ohlendorf 1987), it has been used for wetland management in central California. Since 1954, water delivered to the GWD for wetland management has been a mixture of agricultural drainage and freshwater. Early agricultural drainage primarily consisted of surface water. However, increased amounts of subsurface water from tile drains in expanded areas of irrigated cropland production on the west side of the San Joaquin Valley degraded the quality of GWD water. During 1984-85, 116.3 cubic hectometers (94,300 acre feet) of surface and subsurface drainage water, containing a mean of 45 μg/L selenium, was mixed with approximately 61.7 cubic hectometers (50,000 acre feet) of freshwater and used by the GWD for wetland management (Grassland Water District 1985).

In the early 1980s selenium in subsurface irrigation drainwater caused malformations and reproductive failure in waterfowl at the Kesterson National Wildlife Refuge. Drainwater from other agricultural sources flowed through the nearby Grasslands and was often used to flood wetlands managed for waterfowl by Federal, State, and private entities. Several studies were conducted in the Grasslands and documented elevated selenium levels in waterfowl tissues (Ohlendorf et al. 1987, Paveglio et al. 1992, Hothem and Welsh 1994, Paveglio et al. 1997). During 1984, Ohlendorf et al. (1987) reported elevated concentrations of selenium in nesting aquatic birds from the West Grasslands. These levels were high enough to warrant the issuance of human health advisories.

Exposure of aquatic and aquatic dependent wildlife to agricultural drainwater in this area has been reduced in two stages. Beginning in 1985, agricultural drainwater was no longer applied directly to wetlands, but wetland water supply channels continued to be used periodically to convey agricultural drainwater through wetland areas to the San Joaquin River. After 9 years of this management regime, samples of avian tissue from the Grassland area were collected in 1994 (Paveglio et al. 1997). These samples showed that, while selenium concentrations had declined since the early 1980s, concentrations remained elevated in some species (mean northern shoveler, *Anas clypeata*, liver: 12 mg/kg dry weight (dw); mean black necked stilt, *Himantopus mexicanus*, liver: 11 mg/kg dw). These concentrations were above levels associated with impaired reproduction in birds from laboratory and field studies (Heinz et al. 1989: toxic effect threshold 10 mg/kg; Lemly 1993). Paveglio et al. (1997) projected that, based on concentrations in 1994, another 1-13 years of freshwater management would be needed before aquatic birds in the Grasslands would reach background selenium concentrations in liver.

Since September of 1996, a new drainwater management program, the Grassland Bypass Project (GBP), has been diverting the agricultural drainwater through the San Luis Drain, thus removing drainwater from over 70 miles of Grassland area channels that are used to supply wetlands. The project includes a monitoring program designed to assess the effects of the project on aquatic life in the vicinity of, and downstream from, the outfall of the Grassland Bypass Project (Beckon et al. 2001). The existing monitoring program does not assess intended upstream beneficial effects of the project.

By 2004 the GBP had been in operation for eight years, providing cleaner water in channels supplying broad areas of Federal, State, and private wetlands upstream of the GBP discharge. Therefore, birds and other wildlife that use these wetlands have been expected to exhibit decreases in concentrations of selenium. However, full recovery of the Grassland area wetland ecosystems may not yet be fully realized for two potential reasons: (A) recycling of a persistent reservoir of residual selenium, and (B) continuing input of additional selenium into the ecosystems.

> **Recycling**: The time required for the Grassland ecosystems to depurate selenium is unknown, but is thought to be prolonged for many years with selenium being cycled in the sediment, detritus and benthic organisms of the wetlands and water supply channels. Selenium levels in a flowing system like Salt Slough which had drainwater discharges removed during the GBP dropped to below concern levels in biota after a year (Beckon et al. 2001). However, it can take 10 years or more for selenium to depurate from lentic ecosystems (Lemly 1997).
>
> **Continuing input**: There are several potential sources of selenium continuing to contaminate Grassland area wetlands. Briefly, these sources include (1) continued contamination of the regulated and monitored wetland water supply system, (2) unregulated and unmonitored discharges of agricultural subsurface drainwater from nearby farmland into local ditches and canals, (3) periodic overland flows of floodwater during and immediately following major storm events, and (4) groundwater seepage from adjacent irrigated lands. These factors are discussed in more detail in the DISCUSSION section below.

The purpose of this project is to provide a timely assessment of the degree to which drainwater management initiatives have indeed reduced toxicological risk to wildlife in the most important wetland area remaining in the San Joaquin Valley of California. Additionally, information provided by this project may shed some light on the cause or causes of any continued risk.

The study compares aquatic bird egg and liver data collected over ten years ago when large loads of selenium contaminated source waters in the Grassland area to similar data collected in the same areas in 2004 and 2005, well after selenium was removed from the source waters (September, 1996). This project is a follow-up to the studies conducted from 1986 through 1994 (Hothem and Welsh 1994, Paveglio et al. 1992, Paveglio et al. 1997). Additional data were collected on selenium concentrations in fish, invertebrates, and sediment to assess the selenium risks to fish and wildlife. These data are compared to similar data collected for the Grassland Bypass Project and published selenium threshold effect levels. The objectives of this study are: 1) to evaluate the long-term effectiveness of freshwater to remediate selenium contamination in the West Grasslands; 2) to determine selenium concentrations in aquatic birds; 3) assess hazards selenium may pose to these birds and; 4) determine if the South Grasslands, which received more undiluted drainage water than the North Grasslands, is still more contaminated.

METHODS

Field Sampling. Sediment, aquatic invertebrates, and fish from wetlands in the Grassland area were sampled and analyzed for selenium from five areas that receive water from different or mixed water sources and were representative of areas where eggs were collected by Hothem and Welsh (1994) in 1986 and 1987. Final locations depended on water management decisions regarding seasonal and permanent wetland locations and waterbird roosting and nesting activities in 2004.

Five sediment samples from each area were collected using an Ekman dredge (n=30). The top 3 to 5 centimeters were placed into Whirl-pak bags and placed on ice. Three samples each of three different species of invertebrates were collected from each of the five areas (n=45). Sampling equipment was cleaned between sampling sites. Targeted invertebrates were waterboatmen (family Corixidae), chironomids (family Chironomidae), damselflies (family Agrionidae), dragonflies (family Aeschnidae), and red swamp crayfish (*Procambarus clarkia*). Invertebrates were collected with dip nets, seines, and/or light traps. Three samples each of three different species of fish were collected from each of the five areas (n=45). Targeted fish were mosquitofish (*Gambusia affinis*), fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), sunfish (genus *Lepomis*), and silversides (*Menidia beryllina*). Fish were collected by dip net, seine, and/or minnow traps. All invertebrate and fish samples were separated in stainless steel sieves or porcelain pans using stainless steel tweezers, placed in Whirl-pak bags, labeled, and put on ice. All samples were frozen after returning from the field. Fish and crayfish samples were composites of not less than five fish and had a minimum field weight of 2 grams. Other invertebrate samples were composites weighing no less than 2 grams. Field work followed the interagency monitoring program adopted by the Technical Advisory Committee for the Grasslands Bypass Project and standard operating procedures of the Service's Division of Environmental Contaminants (USBR, et al., 2002; USFWS, 1995).

Eggs were collected (one egg randomly taken from each nest) from the most common aquatic bird species nesting in these areas: mallard (*Anas platyrhynchos*), gadwall (*A. streptera*), American bittern (*Botaurus lentiginosus*), black necked stilt, American avocet (*Recurvirostra americana*), and killdeer (*Charadrius vociferus*). Nests were located by dragging a chain between two all terrain vehicles and, in less accessible areas, by on foot searches. One random egg was collected from each nest located. Collecting eggs from nesting waterbirds minimizes the confounding effects of waterbird movement in the winter season. This is because the eggs represent selenium exposure via the diet in the few weeks before laying, when the birds have settled into a smaller territory. Field sampling methods and QA/QC followed Hothem and Welsh (1994).

To assess risks to wintering aquatic birds, mallards, northern shovelers, northern pintails (*A. acuta*), American coot (*Fulica americana*), and black necked stilts were collected in February 2005 from four areas in the North Grasslands and six areas in the South Grasslands. Because these species represent the range of aquatic bird foraging guilds in the Grasslands, they collectively indicate the health of the entire ecosystem. These areas, duck clubs within the GWD, were previously delineated in accordance with the canal systems historically used to irrigate waterfowl food plants and pasture during the summer and flood wetlands with fresh and drainage water during the fall (Paveglio et al. 1992). The methods and results of this wintering bird component of this project are being reported elsewhere (Paveglio and Kilbride submitted).

A control or reference site was not used for this project. Aquatic bird liver and egg data are compared to liver and egg data collected from the same areas in previous studies when source waters were contaminated with selenium. The egg and liver data along with the fish, invertebrate and sediment data are also compared to similar monitoring data collected for the Grassland Bypass Project in clean and contaminated areas along with extensive published material on the effect levels of selenium in the environment. Data are compared between sites.

Chemical Analyses. After collection, samples were frozen in chemically cleaned jars until analyzed for selenium. Selenium was quantified via hydride generation atomic absorption spectroscopy in compliance with standards set forth by the Service's Analytical Control Facility (ACF) which oversees QA/QC of the laboratory contracts. The detection limit for selenium concentrations were 0.2 µg/g dry weight. Concentrations were corrected based upon recovery rates from spiked samples and percent moisture as appropriate.

RESULTS

Paveglio and Kilbride (submitted) conducted collections during 2005 to determine selenium concentrations in aquatic bird livers after long-term use (20 years) of predominately freshwater for wetland management in the Grasslands. Selenium concentrations in livers were higher for birds from the South Grasslands during 2005, which historically received more undiluted drainage water compared with the North Grasslands. Liver selenium concentrations for stilts from the South Grasslands were within ranges associated with the first incidence of reproductive impairment. Shovelers, coots, and stilts from the South Grasslands during 2005 had 95 percent confidence intervals above the background level.

A total of 62 bird eggs were collected and analyzed for selenium (Appendix 1). Four of these, or 6.5 percent, (Figure 1) exceeded the threshold of concern for avian eggs (6 µg/g dw, Table 1). Those four eggs ranged from 6.0 to 6.9 µg/g.

Table 1. Recommended Ecological Risk Guidelines for Selenium Concentrations (from Beckon et al. 2006).

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water (total recoverable Se)	fish and bird reproduction (via foodchain)	µg/L	< 2	2-5	> 5
Sediment	fish and bird reproduction	mg/kg (dry wt)	< 2	2-4	> 4
Vegetation (as diet)	bird reproduction	mg/kg (dry wt)	< 3	3-7	> 7
Invertebrates (as diet)	bird reproduction	mg/kg (dry wt)	< 3	3-7	> 7
Warmwater Fish (whole body)	fish growth/condition/ survival	mg/kg (dry wt)	< 4	4-9	> 9
Avian egg	egg hatchability	mg/kg (dry wt)	< 6	6-10	>10

Notes:

1. These guidelines, except those for avian eggs, are intended to be population based. Thus, trends in means over time should be evaluated. Guidelines for avian eggs are based on individual level response thresholds (e.g., Heinz, 1996; Skorupa, 1998)

2. A tiered approach is suggested with whole body fish being the most meaningful in assessment of ecological risk in a flowing system.

3. The warmwater fish (whole body) Concern threshold is based on adverse effects on the survival of juvenile bluegill sunfish experimentally fed selenium enriched diets for 90 days (Cleveland et al., 1993). It is the geometric mean of the "no observable effect level" and the "lowest observable effect level."

4. The Toxicity threshold for warmwater fish (whole body) is the concentration at which 10% of juvenile fish are killed (DeForest et al., 1999).

5. The guidelines for vegetation and invertebrates are based on dietary effects on reproduction in chickens, quail and ducks (Wilber, 1980; Martin, 1988; Heinz, 1996).

6. If invertebrate selenium concentrations exceed 6 mg/kg then avian eggs should be monitored (Heinz et al., 1989; Stanley et al., 1996).

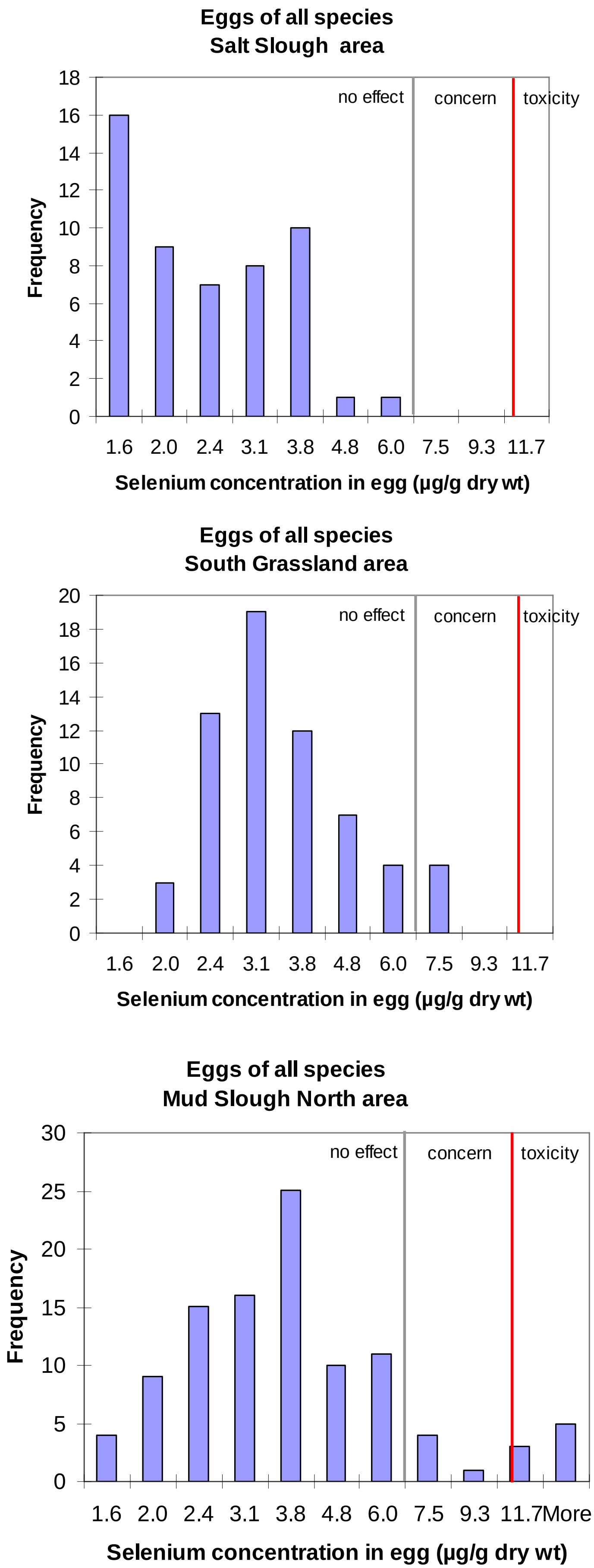


Figure 1. Histograms of selenium concentrations in bird eggs collected in the South Grassland area and in the relatively selenium-clean Salt Slough area and relatively selenium-contaminated Mud Slough area of the North Grassland area for comparison. Bin boundaries are logarithmically scaled.

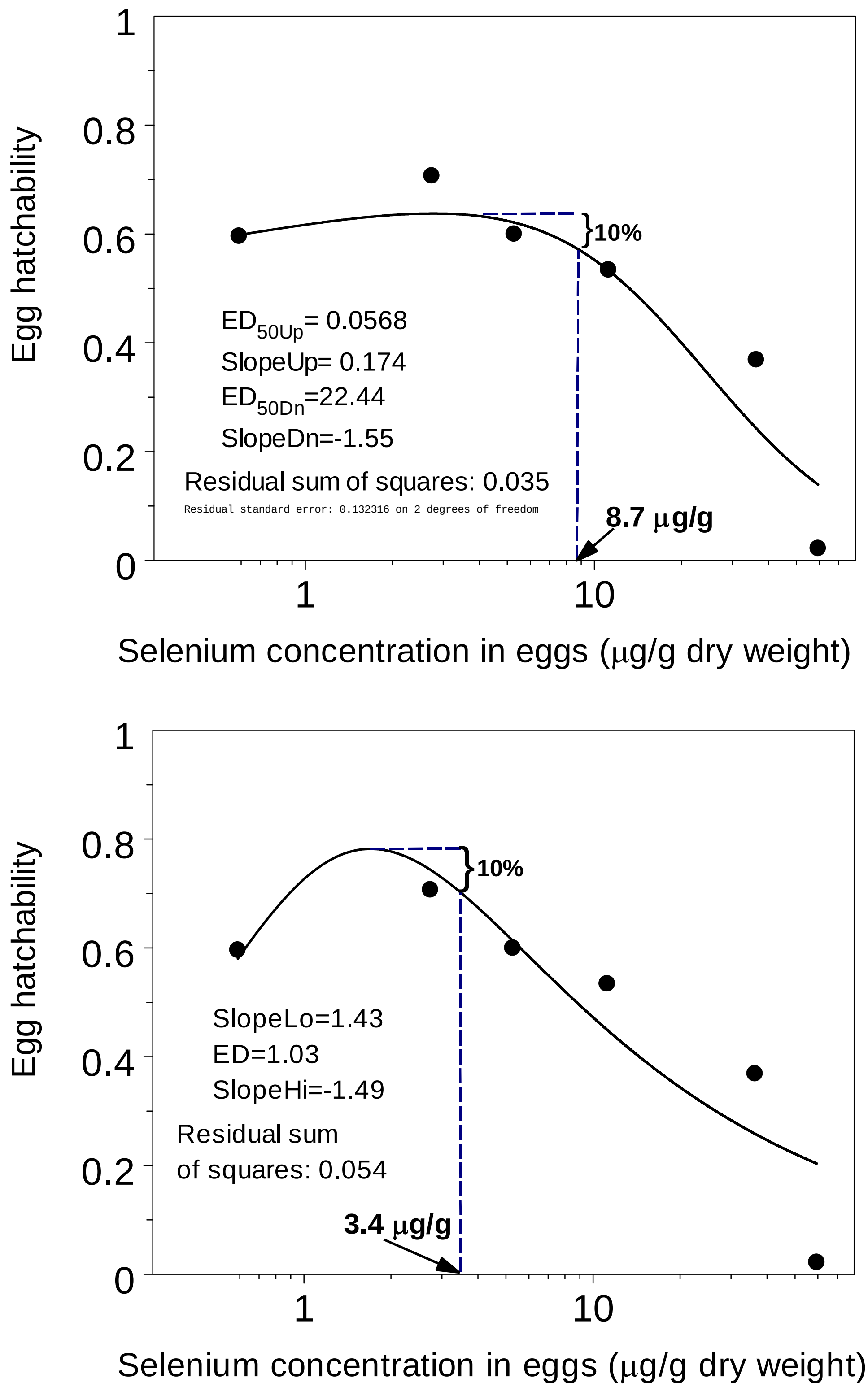


Figure 2. Mallard hatchability data from Heinz et al. 1989 fitted with two alternate hormetic models: the Beckon et al. (in press) model (above) and the Brain and Cousens (1989) model (below).

One egg was collected and analyzed from each of 30 mallard, 11 killdeer, 8 gadwall, 7 American bittern, 3 American avocet, and 3 black-necked stilt nests. Three of the seven American bittern eggs (6.0, 6.1, and 6.5 µg/g selenium) and one of the 30 mallard eggs (6.9 µg/g selenium) equaled or exceeded the threshold of concern (Figure 3). Data from Heinz et al. (1989) on the hatchability of mallard eggs as a function of selenium concentration in the eggs indicates that a mallard egg with a selenium concentration of 6.9 µg/g would suffer a reduction in hatchability of somewhat less than 10 percent or much greater than 10 percent, depending on the model that is fitted to the data (Figure 2). However, most of the eggs collected (Figure 1) were in the range of selenium concentrations that appears to be optimal for hatchability, according to the Heinz et al. (1989) data.

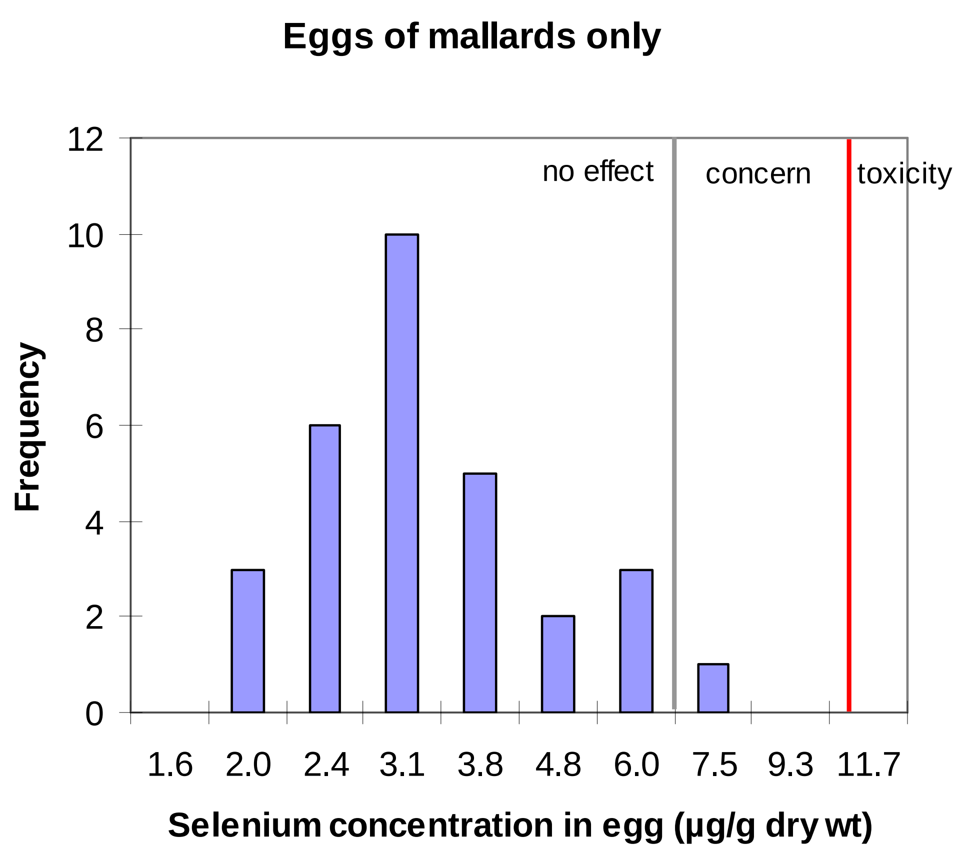


Figure 3. Histogram of selenium concentrations in mallard eggs collected in the South Grassland area. Bin boundaries are logarithmically scaled.

Eighty-nine samples of fish tissue were collected and analyzed for selenium (Appendix 2). Of the 74 whole body fish samples collected (Figure 4), 27 (36.5 percent) exceeded the threshold of concern for selenium in warmwater fish (4 µg/g selenium, Table 1). All 12 samples of striped bass (*Morone saxatilis*, all of them juveniles: 11 from Gadwall Canal at Santa Cruz Gun Club, and one from Camp 13 Ditch at Checkpoint 4) exceeded the threshold of concern for selenium in warmwater fish.

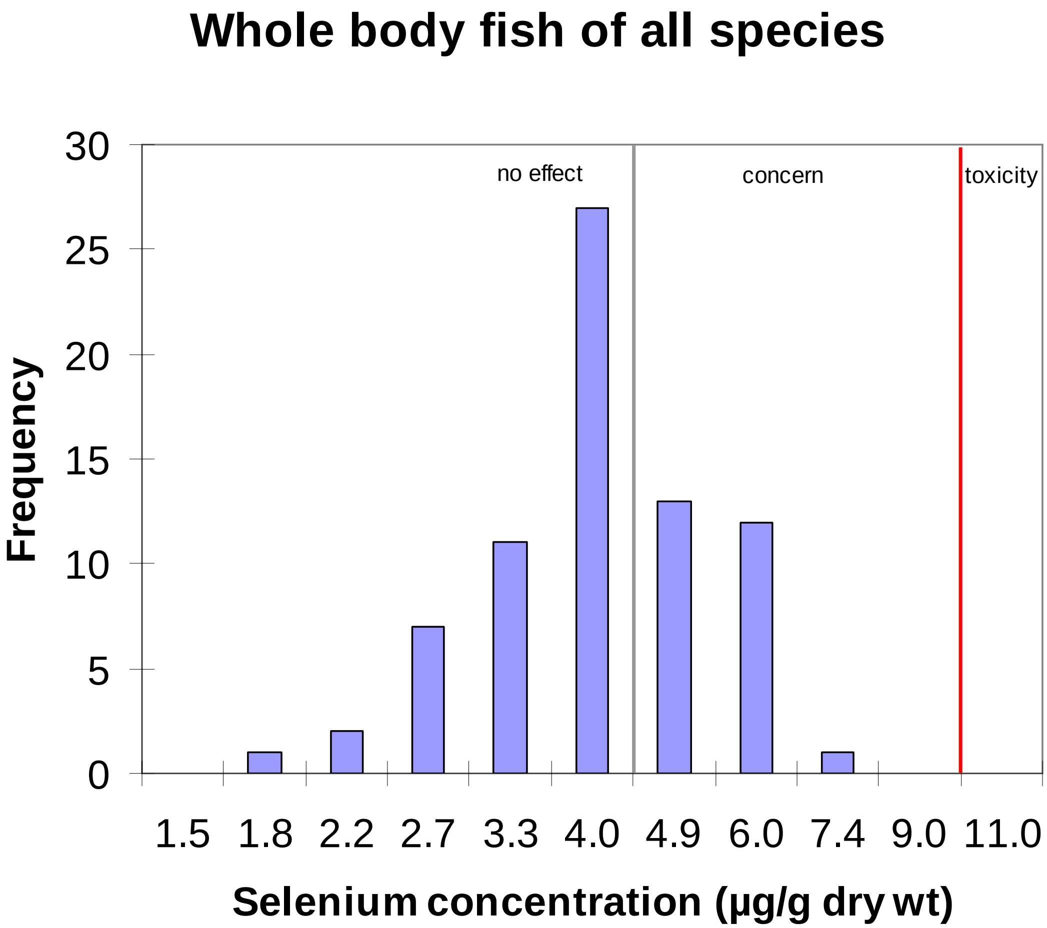


Figure 4. Histogram of whole-body selenium concentrations in fish of all species collected in the South Grassland area. Bin boundaries are logarithmically scaled.

Thirty-two samples of invertebrates were collected in the South Grasslands (Appendix 3). Thirteen of these (40.6 percent, Figure 5) reached or exceeded the threshold of concern for invertebrates as diet for birds (3 µg/g dietary selenium, Table 1). The most effective invertebrate bioaccumulators of selenium were European freshwater snails (Physa) and Siberian shrimp (*Exopalaemon modestus*). The later is a recently introduced species that evidently bioaccumulates selenium more effectively than other aquatic invertebrates in the area, such as red crayfish, that it seems to be replacing (Figure 6).

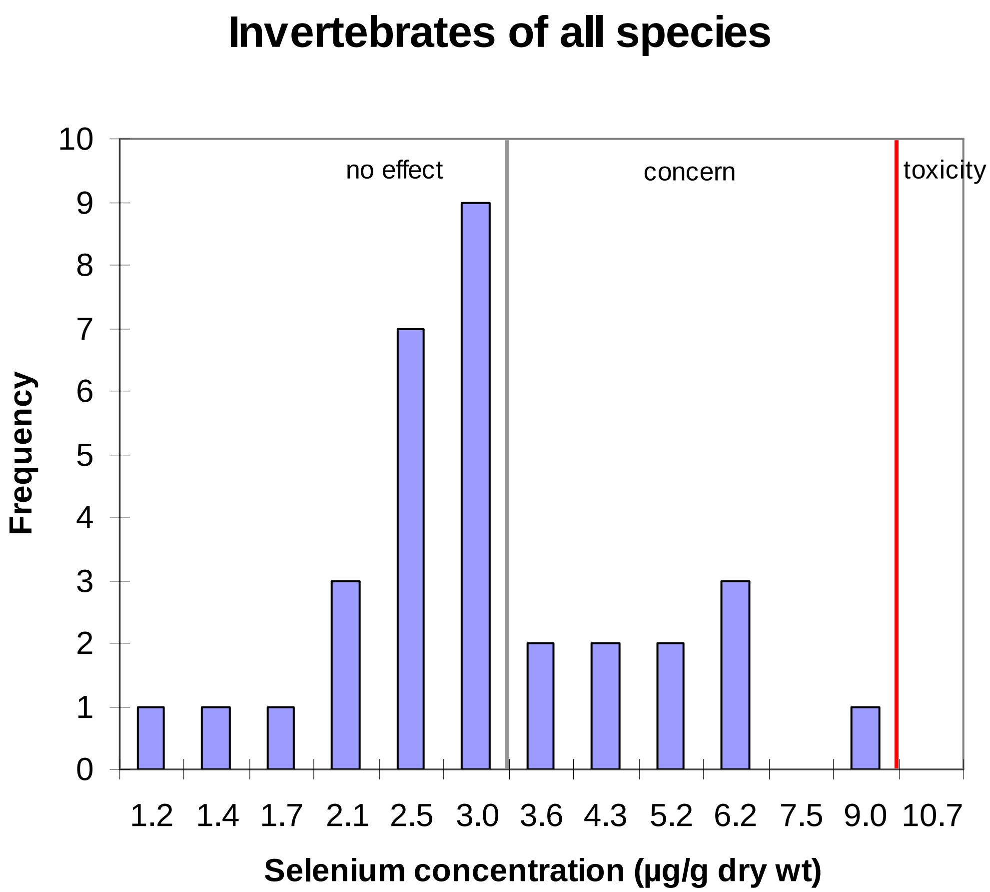


Figure 5. Histogram of selenium concentrations in invertebrates of all species collected in the South Grassland area. Bin boundaries are logarithmically scaled.

A single 12 g bullfrog (*Rana catesbeiana*) tadpole collected from Geis Ditch at Sierra Gun Club MP4 had a selenium concentration of 5.8 µg/g (Appendix 4). The toxicity of selenium to amphibians is too poorly known for the development of specific amphibian toxicity guidelines, but as diet for birds, this sample exceeded the threshold of concern (Table 1).

A common kingsnake (*Lampropeltis getulus*) collected from Mallard Road at Santa Cruz Gun Club had a carcass selenium concentration of 2 µg/g (Appendix 4). As with amphibians, established reptile-specific toxicity guidelines are lacking. However, this tissue selenium concentration is below any known vertebrate effect threshold except for cold-water fish (USFWS 2005).

One sample of sediment was collected from the top one inch of each of three ponds and one ditch (Appendix 4). All of these samples had selenium concentrations below the threshold of effects of selenium in sediment on fish and bird reproduction (2 µg/g, Table 1). The three pond sediment samples had selenium concentrations at or below 0.6 µg/g, well below the threshold of adverse effects.

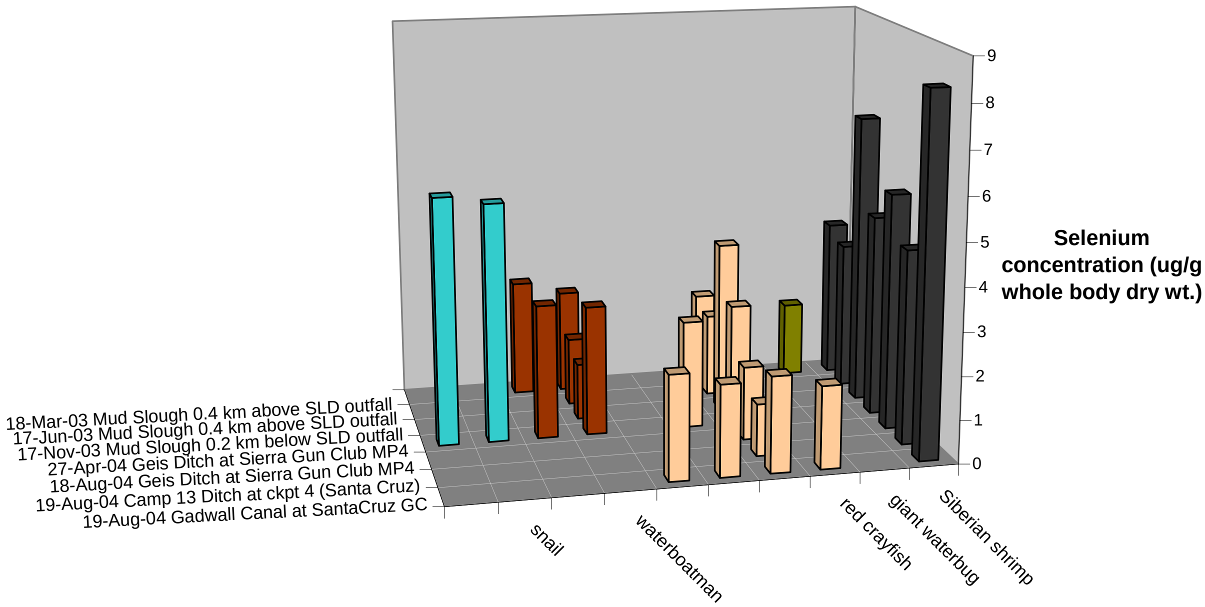


Figure 6. Selenium in Siberian shrimp compared to other invertebrates collected at the same locations and times in the north and south Grasslands areas. Each bar represents a single composite sample.

DISCUSSION

Selenium levels in most bird eggs (93.5 percent) where below the 6.0 µg/g level of concern. Somewhat elevated selenium concentrations in fish, tadpole, and invertebrate samples collected mainly from ditches and canals indicate that the selenium problem in the South Grassland area has improved but remains unresolved. Sediments are thought to serve as an important reservoir of selenium contributing to long-term cycling of selenium in aquatic ecosystems (Lemly and Smith 1987; Lemly 1997) long after influx of selenium has been stopped. Therefore, low concentrations of selenium in pond sediments and pond invertebrates suggest that continuing risks of selenium toxicity in the area are unlikely to be due mainly to residual effects of earlier water management practices, but more likely due to a continuing influx of selenium contamination that has not been fully abated in the area. Supporting this conclusion is the observation that within about one year after implementation of the Grassland Bypass Project, selenium concentrations in the aquatic biota of Salt Slough dropped to background levels (Beckon et al. 2006).

Likely sources of ongoing selenium contamination in Grassland wetlands include (1) continued contamination of the regulated and monitored wetland water supply system; (2) unregulated and unmonitored discharges of agricultural subsurface drainwater from nearby farmland into local ditches and canals; (3) large storm events that can overwhelm the Bypass Project channel, requiring that uncontrollable storm runoff be diverted into wetland supply channels; and (4) groundwater seepage from adjacent irrigated lands.

Monitored wetland water supply system. As with the farmland in the Grassland area, wetlands in both the North and South Grasslands receive most of their water supply from the Sacramento-San Joaquin Delta, pumped southward via the Delta-Mendota Canal (DMC) to the Mendota Pool, thence gravity fed by way of the Central California Irrigation District (CCID) Main Canal to several distribution canals in the area. Agricultural drainwater continues to contaminate this water supply via discharges through check drains on the upslope side of the DMC and from sumps near the south end of the DMC operated by the Bureau of Reclamation as part of their maintenance of the DMC. Further contamination of wetland supply water occurs within the Mendota Pool and CCID Main Canal. Water from the Main Canal reaches the South Grassland wetlands by way of the Camp 13 Ditch and the Agatha Canal (Figure 7). Selenium concentrations in these conveyances have declined since the beginning of the Grassland Bypass Project, but levels still occasionally exceed the water quality objective for wetland water supplies (2 µg/L monthly mean) established by the Central Valley Regional Water Quality Control Board (Figure 8). Similarly, selenium concentrations in the North Grassland water supply channels (San Luis and Santa Fe Canals) have trended downward but have continued to exceed the objective occasionally even after the Grassland Bypass Project was implemented (Figure 9).

Unmonitored local discharges. Some areas of irrigated farm land adjacent to Grassland wetlands are not part of the Grassland Bypass Project. Subsurface drainage from these areas is not regularly monitored, and may be discharged into ditches that enter the water supply system for the Grassland wetlands. Two such areas were identified in a Regional Water Quality Control Board Report by Eppinger and Chilcott (2002). One of these areas is west of the South Grassland wetlands. This area discharges drainwater into the Almond Drive Drain, and thence, by way of the CCID Main Drain, into the CCID Main Canal, which supplies both South and North Grassland wetlands. The second area is southeast of the South Grassland wetlands. This area historically drained into the Poso Drain (also known as the Rice Drain) which enters the South Grassland area from the east.

Storm discharges. Flood waters from the Panoche/Silver Creek watershed contains elevated selenium levels that can overflow agricultural lands, enter water supply channels and drainage ditches, and reach as far east as the Mendota Pool. During and immediately following major storm events, uncontrolled sheet flows across the agricultural landscape inundate and flush drainwater from sumps and open drainage ditches. Such floodwaters sometimes breach or over-top water supply channels, discharging selenium-laden drainwater into the wetlands water supply system. In the Grasslands agricultural area, the subsurface drainage system may be overwhelmed, exceeding, or threatening to exceed, the capacity of the Grassland Bypass Project channel. In such circumstances, Grassland water managers deliberately release into wetland channels (Camp 13 Ditch and/or Agatha Canal) some of the drainwater that would otherwise be routed into the Grassland Bypass channel. Since 1995, such storm events occurred in water years 1995, 1997, 1998 and 2005 and have resulted in substantial spikes in selenium concentrations in the Grassland wetland supply channels (Luoma and Presser, 2000, Grassland Area Farmers 2005).

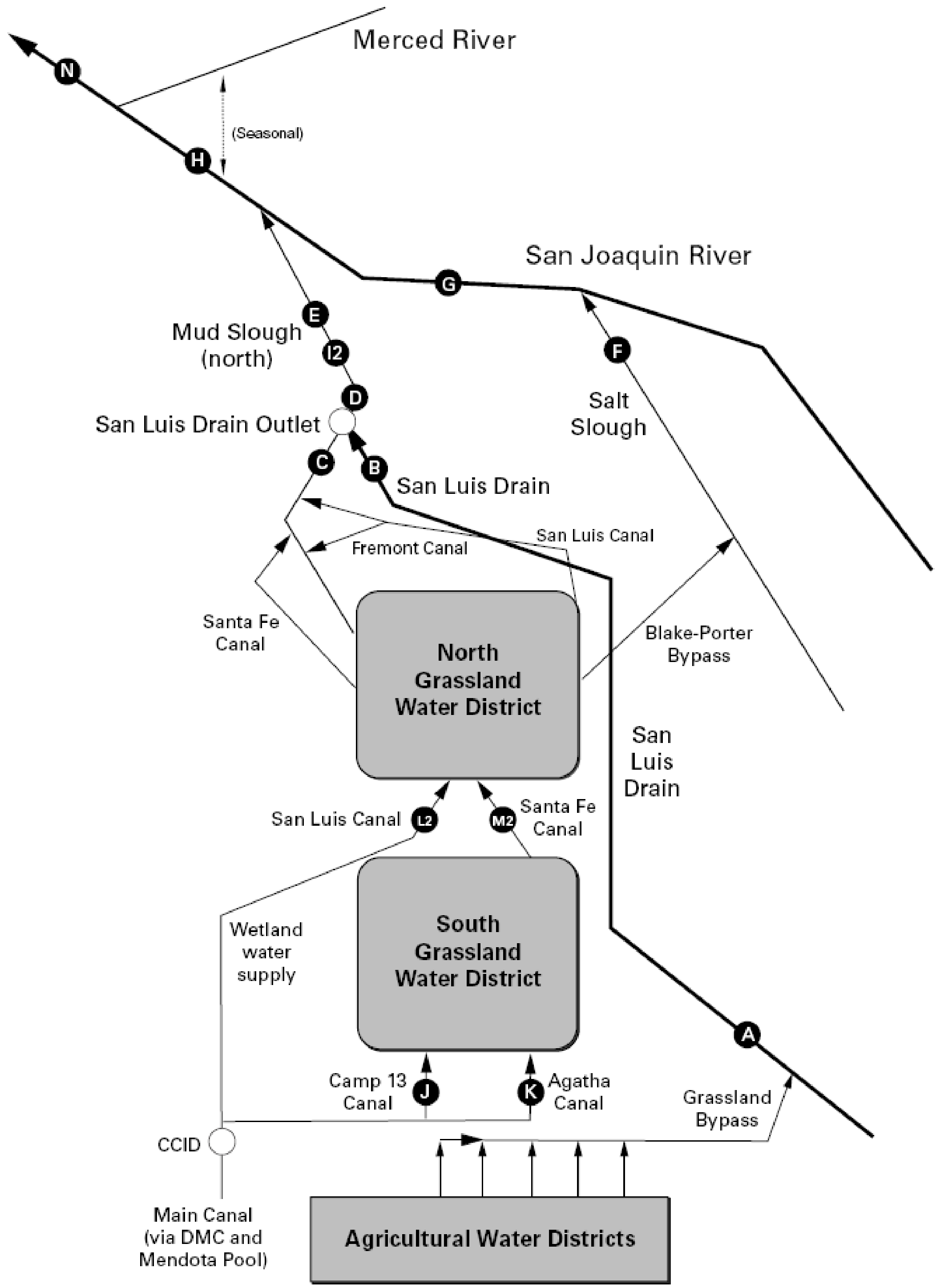


Figure 7. Diagrammatic representation of the water supply for the Grassland area wetlands (from Grassland Bypass Project Monthly Reports).

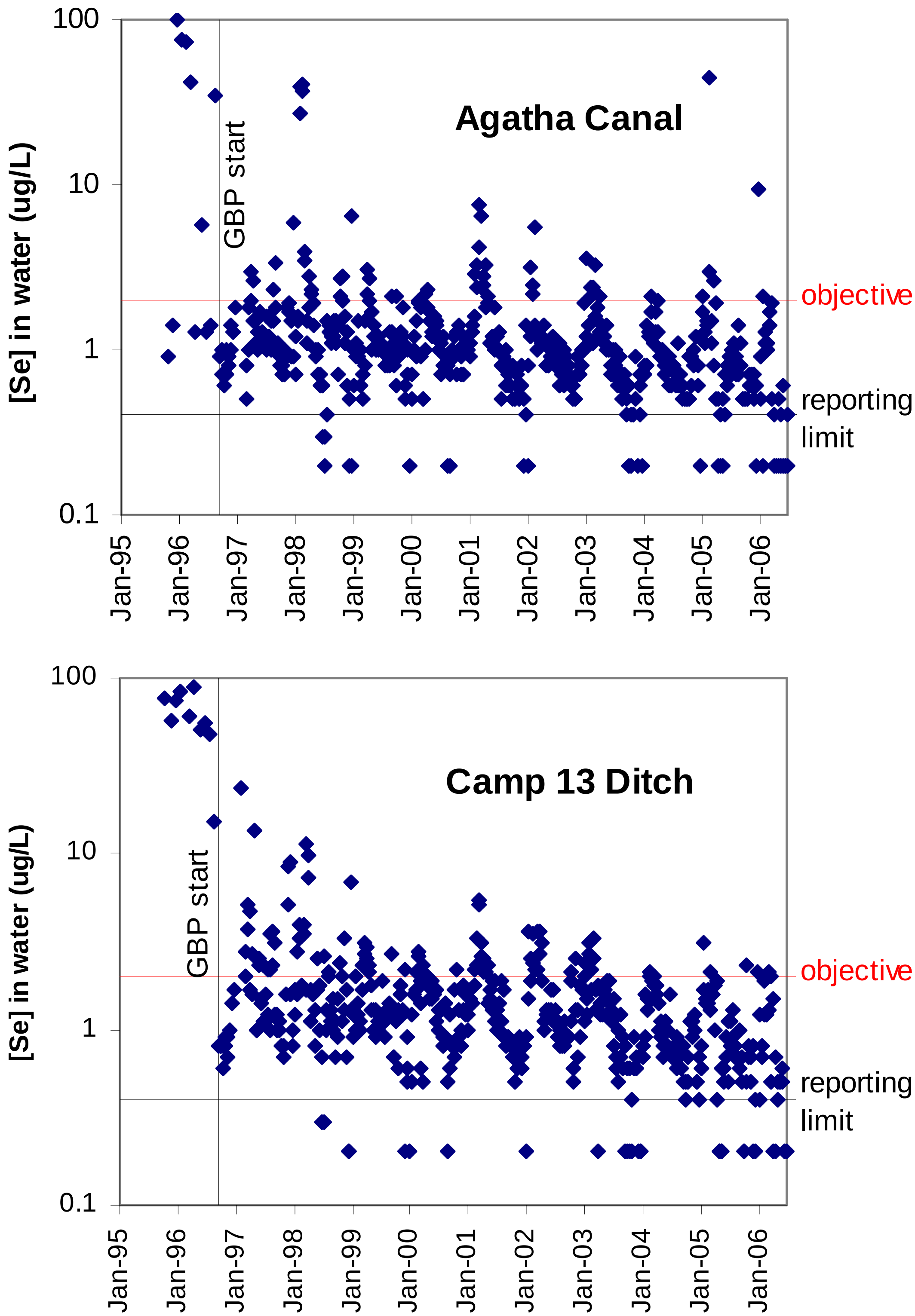
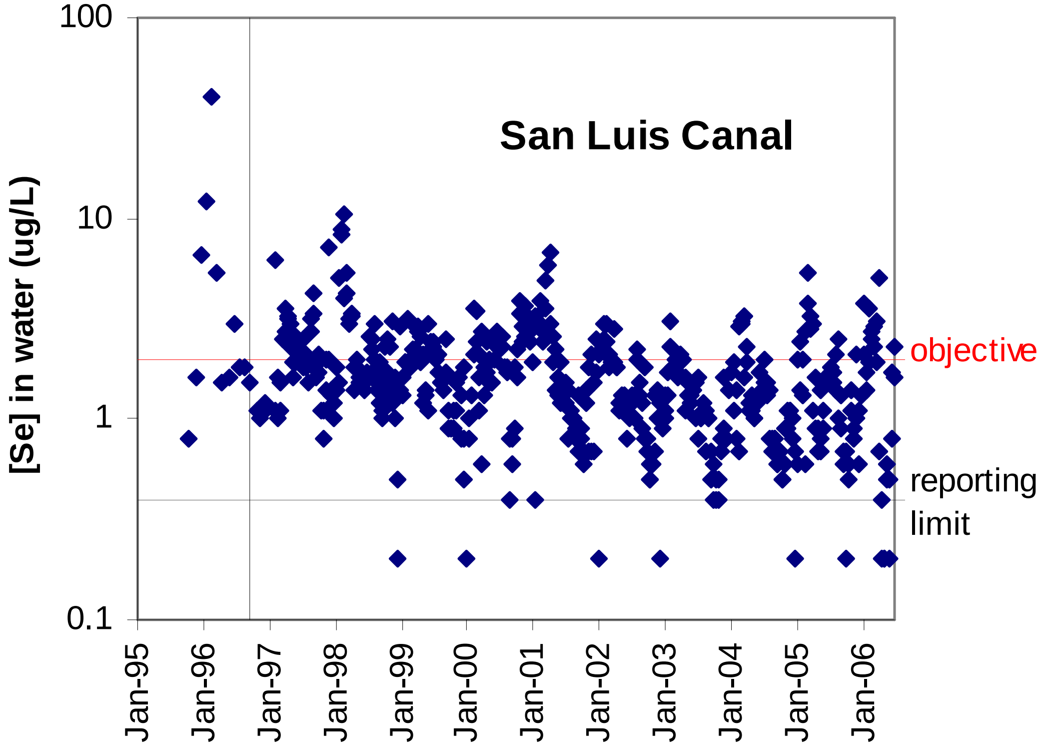


Figure 8. Selenium concentrations in the water supply to the South Grassland wetlands. Weekly water samples were collected by the San Luis and Delta-Mendota Water Authority. The water quality objective (2 µg/L) is a monthly mean. Concentrations below the reporting limit (0.4 µg/L) are shown as 0.2 µg/L (½ the reporting limit).



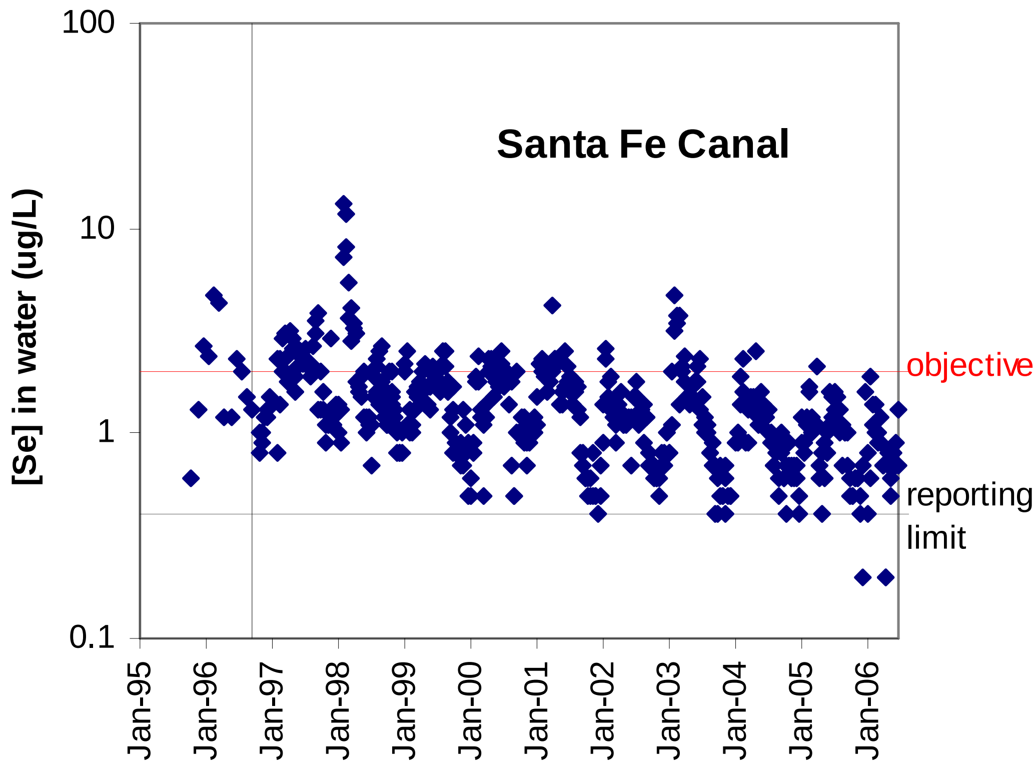


Figure 9. Selenium concentrations in the water supply to the North Grassland wetlands. Weekly water samples were collected by the San Luis and Delta-Mendota Water Authority. The water quality objective (2 µg/L) is a monthly mean. Concentrations below the reporting limit (0.4 µg/L) are shown as 0.2 µg/L (½ the reporting limit).

Lateral groundwater movements. The extent of lateral movements of selenium-laden groundwater in the area is complex and can be considerable in downslope areas. For example, growers in the Firebaugh Water District have noted that sumps in fallow fields continue to fill up with seleniferous groundwater long after cessation of irrigation on those fields. Much of the South Grassland area is particularly vulnerable to lateral groundwater flows from nearby upslope farms where selenium in the ground water is especially elevated. Frio (1997) modeled groundwater flow in the Panoche Water District upslope of the South Grassland area and found that 11 percent of Panoche's drainage was from lateral or upward flows. In the downslope areas of the Panoche Water District lateral groundwater movement could be as far as 3.6 km before being intercepted in drainage systems. Also, upward groundwater flows tended to have higher selenium concentrations.

MANAGEMENT RECOMMENDATIONS

Off-refuge recommendations

To remove the risk of selenium toxicity to the wildlife in this area, all of the sources of contamination listed above must be addressed. Some of the monitored and unmonitored discharges can be removed from the water supply channels by diverting them into the Grassland Bypass Project collection system. Land retirement of the drainage impaired lands would fully remove the source of selenium from the drainage system. Small scale integrated on-farm drainage management systems could be implemented for lesser discharges (e.g. see http://www.sjd.water.ca.gov/drainage/ifdm/). These systems reuse drainwater on salt tolerant crops, thus reducing the volume of drainwater which is then evaporated in small solar evaporation systems that prevent ponding.

Stormwater discharges are difficult to predict and control. Continued use of the San Luis Drain to convey smaller storm flows to the San Joaquin River may be appropriate. Flood control systems on the Panoche and Silver Creek watersheds have been considered. Retention dams on the creeks can provide controlled release of flood flows but may also create selenium contaminated habitat that might be attractive to wildlife. Such habitat could pose greater selenium risks than those currently seen in the Grassland areas. These risks would have to be thoroughly evaluated and weighed against risks associated with other selenium and flood control programs.

Refuge management recommendations

Another possible approach to ameliorating the selenium problem might be to divert into North Grassland wetlands some of the water that currently flows into Salt Slough from Mud Slough South. The San Luis National Wildlife Refuge Complex (SLNWRC) has 28,700 acre-feet of water rights to Salt Slough. Since the implementation of the Grassland Bypass Project, the selenium concentrations in Salt Slough (Figure 10) have dropped to lower levels than the concentrations in the channels (San Luis Canal and Santa Fe Canal) that supply water to the western units of the SLNWRC (Figure 9). Such a diversion may have the added benefit of reducing the salinity of source water for the wetlands of the western SLNWRC, thereby reducing the salt loads discharged by these wetlands into the San Joaquin River. Providing water more directly to the SLNWRC wetlands from the DMC would also reduce selenium levels and salt loads.

Finally, a critical component of selenium monitoring in the Grasslands Area, waterfowl muscle tissue, should be funded to assess health concerns of hunters and the state Se health advisory.

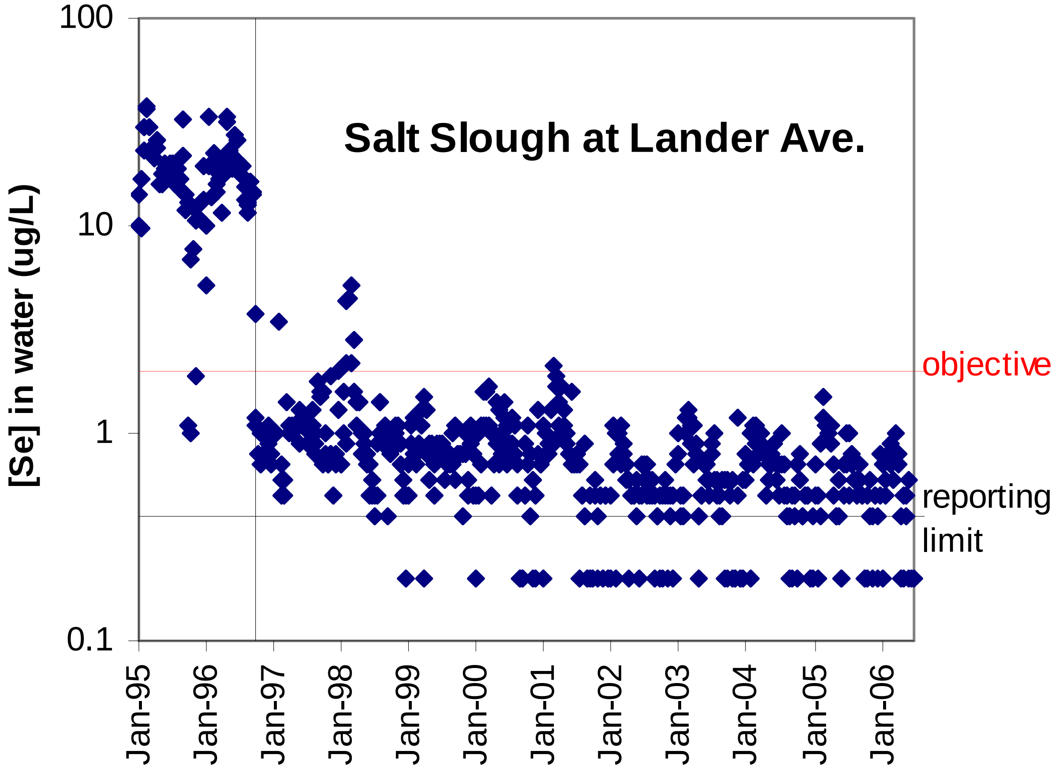


Figure 10. Selenium concentrations in Salt Slough. Weekly water samples were collected by the Central Valley Regional Water Quality Control Board. The water quality objective (2 µg/L) is a monthly mean. Concentrations below the reporting limit (0.4 µg/L) are shown as 0.2 µg/L (½ the reporting limit).

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APPENDIX 1

BIRD EGGS

Drainage (Source)

Geis Ditch

Sample ID	Collect Date	Location	Common Name	% Moist	Se Res Dry ppm
AB0201AR	5/7/2004	Sand Lake Development Company	american bittern	80.5	4.7
AB1501AR	6/15/2004	Sierra Gun Club	american bittern	80.6	4.6
AB2701AR	5/7/2004	Elsie Geis Gun Club	american bittern	82.6	6.1
040201AR	5/7/2004	Sand Lake Development Company	gadwall	68.9	3.4
041501AR	6/15/2004	Sierra Gun Club	gadwall	67.3	2.5
041502AR	6/15/2004	Sierra Gun Club	gadwall	69.3	2
042701AR	5/21/2004	Elsie Geis Gun Club	gadwall	69.3	2.1
0502001AR	4/24/2004	Sand Lake Development Company	mallard	68.3	2.6
0502003AR	4/24/2004	Sand Lake Development Company	mallard	69.4	2
050202AR	5/7/2004	Sand Lake Development Company	mallard	70.4	2.9
050204AR	5/7/2004	Sand Lake Development Company	mallard	69.2	2.3
050205AR	5/21/2004	Sand Lake Development Company	mallard	68.1	2.7
050206AR	5/21/2004	Sand Lake Development Company	mallard	67.3	4.1
050207AR	5/21/2004	Sand Lake Development Company	mallard	67.9	2.8
050207BR	5/21/2004	Sand Lake Development Company	mallard	69.1	2.6
051501AR	5/21/2004	Sierra Gun Club	mallard	69.6	3.2
051502AR	6/15/2004	Sierra Gun Club	mallard	68.7	3.4
051502B	6/15/2004	Sierra Gun Club	mallard	69.1	3.2
051502C	6/15/2004	Sierra Gun Club	mallard	69.2	3.2
051502D	6/15/2004	Sierra Gun Club	mallard	69	3
051503AR	6/15/2004	Sierra Gun Club	mallard	68.1	1.9
052701AR	5/7/2004	Elsie Geis Gun Club	mallard	71.2	6.9
052702AR	5/7/2004	Elsie Geis Gun Club	mallard	69.3	2
052703AR	5/7/2004	Elsie Geis Gun Club	mallard	69.1	2.2
052704AR	5/21/2004	Elsie Geis Gun Club	mallard	68.9	1.9
052705AR	6/15/2004	Elsie Geis Gun Club	mallard	68.7	2.9

Camp 13 Ditch

041401AR	6/15/2004	Britto Gun Club	gadwall	68.8	3.9
041402AR	6/15/2004	Britto Gun Club	gadwall	68.5	2.5
051401AR	5/7/2004	Britto Gun Club	mallard	70.7	1.8

Fraser Ditch (Helm Canal)

131301AR	5/18/2004	Fraser Gun Club Brood Pond	killdeer	73.2	2.5
041301AR	6/7/2004	Fraser Gun Club Brood Pond	gadwall	70.3	3.1

Gadwall Canal (Camp 13 Ditch)

030401AR	5/18/2004	Santa Cruz Gun Club Brood Pond	american avocet	73.7	3.6

030402AR	5/18/2004	Santa Cruz Gun Club Brood Pond	american avocet	74.4	3.1
030403AR	5/18/2004	Santa Cruz Gun Club Brood Pond	american avocet	72.8	3
020401AR	5/7/2004	Santa Cruz Gun Club Brood Pond	black-necked stilt	74.9	3.1
020402AR	5/18/2004	Santa Cruz Gun Club Brood Pond	black-necked stilt	76.5	3.1
020403AR	5/18/2004	Santa Cruz Gun Club Brood Pond	black-necked stilt	73.5	2.8
040401AR	5/21/2004	Santa Cruz Gun Club	gadwall	67.4	2.8
050401AR	5/3/2004	Santa Cruz Gun Club	mallard	68.9	5
050401BS	5/3/2004	Santa Cruz Gun Club	mallard	68.9	5.6
050401CS	5/3/2004	Santa Cruz Gun Club	mallard	69.6	4.6
050402AR	5/3/2004	Santa Cruz Gun Club	mallard	69.5	5.3
050403AR	5/7/2004	Santa Cruz Gun Club	mallard	70.6	2.5
050404AR	5/21/2004	Santa Cruz Gun Club	mallard	68.9	2.2
050405AR	5/21/2004	Santa Cruz Gun Club	mallard	70.3	2.2
050406AR	5/21/2004	Santa Cruz Gun Club	mallard	68.4	2.7
050407AR	5/21/2004	Santa Cruz Gun Club	mallard	70.1	3.4
AB0401AR	5/3/2004	Santa Cruz Gun Club	american bittern	82.1	6
AB0402AR	5/21/2004	Santa Cruz Gun Club	american bittern	81.7	6.5
AB0403AR	7/1/2004	Santa Cruz Gun Club	american bittern	81.1	5.8
130401AR	5/3/2004	Santa Cruz Gun Club Brood Pond	killdeer	73.1	3.1
130402AR	5/3/2004	Santa Cruz Gun Club Brood Pond	killdeer	70.9	4
130403AR	5/18/2004	Santa Cruz Gun Club Brood Pond	killdeer	74	2.5
130404AR	6/7/2004	Santa Cruz Gun Club Brood Pond	killdeer	72.4	2.2
130405AR	6/7/2004	Santa Cruz Gun Club Brood Pond	killdeer	70.3	2.5
130406AR	5/7/2004	Santa Cruz Gun Club Brood Pond	killdeer	73.3	2.7
		Sorsky Ditch (from Camp 13 & 240 Ditch)			
052501AR	5/21/2004	Redfern Duck Club Brood Pond	mallard	69.9	2.6
AB2501AR	6/15/2004	Redfern Duck Club	american bittern	81.3	4.5
130101AR	5/18/2004	Mallard Road S of Bovet Gun Club	killdeer	72.1	2
131401AR	5/7/2004	Britto Gun Club Compound	killdeer	73	2.2
131402AR	5/7/2004	Britto Gun Club Compound	killdeer	72.1	2.1
131403AR	6/15/2004	Britto Gun Club Compound	killdeer	72.4	2.1

APPENDIX 2

FISH

Sample ID	Collect Date	Location/Drainage	Weight grams	Matrix	Genus/Species	Common Name	% Moisture	Se DL Rel	Se Res Dry ppm
GDSGBG01	8/18/2004	Geis Ditch at Sierra Gun Club MP4	2.1	whole	Lepomis	bluegill	76		5.2
C13MCBG01	8/18/2004	Camp 13 Ditch at Main Canal	22.6	whole	Lepomis	bluegill	74.5		3.3
C13MCBG02	8/18/2004	Camp 13 Ditch at Main Canal	12.4	whole	Lepomis	bluegill	74.1		2.9
C1304BG01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	108.6	whole	Lepomis	bluegill	74.7		2.9
C1304BB01	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	20.5	whole	Ameiurus	brown bullhead	80.3		3.4
GSCBB01	8/19/2004	Gadwall Canal @ Santa Cruz GC	226	whole	Ameiurus	brown bullhead	74.7		1.8
GSCBB02	8/19/2004	Gadwall Canal @ Santa Cruz GC	147	whole	Ameiurus	brown bullhead	77.1		2.5
GSCBB03	8/19/2004	Gadwall Canal @ Santa Cruz GC	177	whole	Ameiurus	brown bullhead	78.6		2.5
GSCBB04	8/19/2004	Gadwall Canal @ Santa Cruz GC	199	whole	Ameiurus	brown bullhead	76.8		2.1
GDSGCF01L	8/19/2004	Geis Ditch at Sierra Gun Club MP4	31.8	Liver	Ictalurus	channel catfish	79.2		12
GDSGCF01F	8/19/2004	Geis Ditch at Sierra Gun Club MP4	15.6	Muscle	Ictalurus	channel catfish	81.7		2.6
GDSGC03E	8/19/2004	Geis Ditch at Sierra Gun Club MP4	644	Eggs	Cyprinus	common carp	65.9		7.7
C1304C01E	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	180	Eggs	Cyprinus	common carp	70.1		6.8
C1304C02E	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	535	Eggs	Cyprinus	common carp	67.9		6
GDSGC01L	8/19/2004	Geis Ditch at Sierra Gun Club MP3	11.2	Liver	Cyprinus	common carp	55.6		3.7
GDSGC02L	8/19/2004	Geis Ditch at Sierra Gun Club MP4	4.6	Liver	Cyprinus	common carp	68.5		9.3

GDSGC03L	8/19/2004	Geis Ditch at Sierra Gun Club MP4	8.8	Liver	Cyprinus	common carp	76.6		15
C1304C01L	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	10.1	Liver	Cyprinus	common carp	75.8		9.8
C1304C02L	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	9	Liver	Cyprinus	common carp	74.8		13
GDSGC01F	8/19/2004	Geis Ditch at Sierra Gun Club MP4	18.6	Muscle	Cyprinus	common carp	75.5		5.6
GDSGC02F	8/19/2004	Geis Ditch at Sierra Gun Club MP4	25.4	Muscle	Cyprinus	common carp	79.9		9.6
GDSGC03F	8/19/2004	Geis Ditch at Sierra Gun Club MP4	18.1	Muscle	Cyprinus	common carp	80.9		9.9
C1304C01F	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	15.5	Muscle	Cyprinus	common carp	80.1		4.9
C1304C02F	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	15.4	Muscle	Cyprinus	common carp	78.2		4.7
GCSC01	8/18/2004	Gadwall Canal @ Santa Cruz GC	20.5	whole	Cyprinus	common carp	79		5.8
GCSC02	8/18/2004	Gadwall Canal @ Santa Cruz GC	15.3	whole	Cyprinus	common carp	79.9		5.8
SDFM01	8/19/2004	Sorsky Ditch @ Outdoor Sports Club	38.1	whole	Pimephales	fathead minnow	75		2.2
04GEIS15	4/27/2004	Geis Ditch at Sierra Gun Club MP4	15.7	whole	Notemigonus	golden shiner	73.2		3.4
04GEIS12	4/27/2004	Geis Ditch at Sierra Gun Club MP4	47.3	whole	Lepomis	green sunfish	77.4		3.6
C1304GS01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	11.3	whole	Lepomis	green sunfish	77.9		3.9
C1304GS02	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	3.9	whole	Lepomis	green sunfish	75.5		3.9
04GEIS01	4/27/2004	Geis Ditch at Sierra Gun Club MP4	12.2	whole	Menidia	inland silverside	78.8		3.2
04GEIS02	4/27/2004	Geis Ditch at Sierra Gun Club MP4	52.1	whole	Menidia	inland silverside	77.8		3.4
04GEIS03	4/27/2004	Geis Ditch at Sierra Gun Club MP4	11.1	whole	Menidia	inland silverside	78.6		2.9
04GEIS04	4/27/2004	Geis Ditch at Sierra Gun Club MP4	17.8	whole	Menidia	inland silverside	78.5		3.4

04GEIS05	4/27/2004	Geis Ditch at Sierra Gun Club MP4	17.6	whole	Menidia	inland silverside	78.8		3.3
04GEIS06	4/27/2004	Geis Ditch at Sierra Gun Club MP4	9.3	whole	Menidia	inland silverside	78.7		3.4
04GEIS07	4/27/2004	Geis Ditch at Sierra Gun Club MP4	19.2	whole	Menidia	inland silverside	78.9		3.1
GDSGIS08	8/18/2004	Geis Ditch at Sierra Gun Club MP4	37.9	whole	Menidia	inland silverside	77.5		6.2
C1304IS01	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	13.6	whole	Menidia	inland silverside	76.5		3.4
C1304IS02	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	10.4	whole	Menidia	inland silverside	77		3.5
C1304IS03	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	12	whole	Menidia	inland silverside	76.3		3.4
C1304IS04	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	9.9	whole	Menidia	inland silverside	77.2		3.4
C1304IS05	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	12.4	whole	Menidia	inland silverside	76.6		3.6
C1304IS06	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	9.2	whole	Menidia	inland silverside	77.3		3.5
C1304IS07	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	10.5	whole	Menidia	inland silverside	76.7		3.4
C1304IS08	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	11.1	whole	Menidia	inland silverside	77.8		3.6
C1304IS09	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	10.7	whole	Menidia	inland silverside	77.7		3.6
GCSCIS01	8/18/2004	Gadwall Canal @ Santa Cruz GC	3.7	whole	Menidia	inland silverside	74.9		5.1
SDIS01	8/19/2004	Sorsky Ditch @ Outdoor Sports Club	47.3	whole	Menidia	inland silverside	77.1		2.2
GCSCLB02	8/18/2004	Gadwall Canal @ Santa Cruz GC	37.3	whole	Micropterus	largemouth bass	74.8		5.3
GSCLB01	8/19/2004	Gadwall Canal @ Santa Cruz GC	169	whole	Micropterus	largemouth bass	77.2		5.4
04GEIS08	4/27/2004	Geis Ditch at Sierra Gun Club MP4	4.7	whole	Cyprinella	red shiner	78.2		3.8
04GEIS09	4/27/2004	Geis Ditch at Sierra Gun Club MP4	4.7	whole	Cyprinella	red shiner	73.9		3.7

04GEIS10	4/27/2004	Geis Ditch at Sierra Gun Club MP4	5	whole	Cyprinella	red shiner	77.8		3.9
04GEIS13	4/27/2004	Geis Ditch at Sierra Gun Club MP4	4.8	whole	Cyprinella	red shiner	78.1		4.2
04GEIS14	4/27/2004	Geis Ditch at Sierra Gun Club MP4	8	whole	Cyprinella	red shiner	77.9		4.1
04GEIS24	4/27/2004	Geis Ditch at Sierra Gun Club MP4	3.7	whole	Cyprinella	red shiner	75.7		3.8
04GEIS25	4/27/2004	Geis Ditch at Sierra Gun Club MP4	6.6	whole	Cyprinella	red shiner	77.3		4
04GEIS26	4/27/2004	Geis Ditch at Sierra Gun Club MP4	6.6	whole	Cyprinella	red shiner	76.5		3.9
C1304RS01	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	2.3	whole	Cyprinella	red shiner	71.1		2.8
SDRS01	8/19/2004	Sorsky Ditch @ Outdoor Sports Club	45.2	whole	Cyprinella	red shiner	76.1		2.2
C1304SB02	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	3.3	whole	Micropterus	smallmouth bass	75.1		3.1
C1304SB01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	42.2	whole	Morone	striped bass	76		4.1
GCSCSB01	8/19/2004	Gadwall Canal @ Santa Cruz GC	55	whole	Morone	striped bass	75		5.6
GCSCSB02	8/19/2004	Gadwall Canal @ Santa Cruz GC	40	whole	Morone	striped bass	74.6		4.4
GCSCSB03	8/19/2004	Gadwall Canal @ Santa Cruz GC	34	whole	Morone	striped bass	76.2		4.8
GCSCSB04	8/19/2004	Gadwall Canal @ Santa Cruz GC	32	whole	Morone	striped bass	76.6		4.7
GCSCSB05	8/19/2004	Gadwall Canal @ Santa Cruz GC	44	whole	Morone	striped bass	75.3		4.4
GCSCSB06	8/19/2004	Gadwall Canal @ Santa Cruz GC	52	whole	Morone	striped bass	74.6		4.6
GCSCSB07	8/19/2004	Gadwall Canal @ Santa Cruz GC	32	whole	Morone	striped bass	76.6		5.4
GCSCSB08	8/19/2004	Gadwall Canal @ Santa Cruz GC	50	whole	Morone	striped bass	77		5.3
GCSCSB09	8/19/2004	Gadwall Canal @ Santa Cruz GC	52	whole	Morone	striped bass	75.4		5.6
GCSCSB10	8/19/2004	Gadwall Canal @ Santa Cruz GC	47	whole	Morone	striped bass	75.7		5
GCSCSB11	8/19/2004	Gadwall Canal @ Santa Cruz GC	36	whole	Morone	striped bass	74.5		4.5
C1304TS01	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	10.5	whole	Dorosoma	threadfin shad	75.5		2.9

C1304TS02	8/18/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	29.4	whole	Dorosoma	threadfin shad	79.4		2.6
GSCTS01	8/19/2004	Gadwall Canal @ Santa Cruz GC	76	whole	Dorosoma	threadfin shad	74.8		3.2
GSCTS02	8/19/2004	Gadwall Canal @ Santa Cruz GC	78	whole	Dorosoma	threadfin shad	74.9		3.3
GSCTS03	8/19/2004	Gadwall Canal @ Santa Cruz GC	66	whole	Dorosoma	threadfin shad	73.2		2.8
GCSCTS04	8/18/2004	Gadwall Canal @ Santa Cruz GC	23.4	whole	Dorosoma	threadfin shad	80		4.7
04GEIS11	4/27/2004	Geis Ditch at Sierra Gun Club MP4	7.3	whole	Gambusia	western mosquitofish	75.5		3
GDSGMF01	8/19/2004	Geis Ditch at Sierra Gun Club MP4	4.5	whole	Gambusia	western mosquitofish	75.4		4.6
GDSGMF02	8/19/2004	Geis Ditch at Sierra Gun Club MP4	5.1	whole	Gambusia	western mosquitofish	76.2		4.4
GDSGMF03	8/19/2004	Geis Ditch at Sierra Gun Club MP4	7.7	whole	Gambusia	western mosquitofish	75.4		4.7
C1304MF01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	1.2	whole	Gambusia	western mosquitofish	70.4		3.8
GCSCMF01	8/18/2004	Gadwall Canal @ Santa Cruz GC	11.9	whole	Gambusia	western mosquitofish	76.9		5.3
SDMF01	8/19/2004	Sorsky Ditch @ Outdoor Sports Club	40.9	whole	Gambusia	western mosquitofish	78		2.2
C1304WC01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	202.4	whole	Ameiurus	white catfish	76.6		1.6

APPENDIX 3

INVERTEBRATES

Sample ID	Collect Date	Location/Drainage	Weight grams	Matrix	Genus/Species	Common Name	% Moisture	Se DL Rel	Se Res Dry ppm
SCNO02	4/28/2004	Santa Cruz Gun Club Brood Pond	2.3	whole	Notonectidae	Backswimmer	76.2		4.2
SCNO03	4/28/2004	Santa Cruz Gun Club Brood Pond	2.1	whole	Notonectidae	Backswimmer	74.2		4.2
RFNO01	4/28/2004	Redfern Duck Club Brood Pond	8.1	whole	Notonectidae	Backswimmer	84.4		2.6
RFNO02	4/28/2004	Redfern Duck Club Brood Pond	2.4	whole	Notonectidae	Backswimmer	78.6		2.2
RFNO03	4/28/2004	Redfern Duck Club Brood Pond	2.2	whole	Notonectidae	Backswimmer	77		2.5
04GEIS27	4/27/2004	Geis Ditch at Sierra Gun Club MP4	3	whole	Physella	European physa	70.9		5.7
04GEIS28	4/27/2004	Geis Ditch at Sierra Gun Club MP4	3.1	whole	Physella	European physa	70.8		5.5
SCAI02	4/28/2004	Santa Cruz Gun Club Brood Pond	12.5	whole	Daphnia	None	92.7		2.7
SCAI03	4/28/2004	Santa Cruz Gun Club Brood Pond	14.9	whole	Daphnia	None	93.7		2.6
04GEIS16	4/27/2004	Geis Ditch at Sierra Gun Club MP4	4.3	whole	Procambarus	red swamp crayfish	81		2.8
04GEIS17	4/27/2004	Geis Ditch at Sierra Gun Club MP4	7.4	whole	Procambarus	red swamp crayfish	80.7		2.5
GSSGCD02	8/19/2004	Gadwall Canal @ Santa Cruz GC	133	whole	Procambarus	red swamp crayfish	69.6		1.9
GDSGCD01	8/19/2004	Geis Ditch at Sierra Gun Club MP4	178	whole	Procambarus	red swamp crayfish	68.3		1.7
C1304CF01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	84.5	whole	Procambarus	red swamp crayfish	76.7		1.2
GSCCF01	8/19/2004	Gadwall Canal @ Santa Cruz GC	95	whole	Procambarus	red swamp crayfish	71.8		2.4
GSCCF02	8/19/2004	Gadwall Canal @ Santa Cruz GC	111	whole	Procambarus	red swamp crayfish	71.8		2.1
GSCCF03	8/19/2004	Gadwall Canal @ Santa Cruz GC	76	whole	Procambarus	red swamp crayfish	70.7		2.2
SDCD01	8/19/2004	Sorsky Ditch @ Outdoor Sports Club	58.2	whole	Procambarus	red swamp crayfish	76.5		1.3
04GEIS18	4/27/2004	Geis Ditch at Sierra Gun Club MP4	38.8	whole	Exopalaemon	siberian prawn	78		4.7
GDSGSS02	8/18/2004	Geis Ditch at Sierra Gun Club MP4	3.6	whole	Exopalaemon	siberian prawn	78.2		5.5
C1304SS01	8/19/2004	Camp 13 Ditch at ckpt 4 (Santa Cruz)	6	whole	Exopalaemon	siberian prawn	76		4.5
GCSCSS01	8/18/2004	Gadwall Canal @ Santa Cruz GC	13.1	whole	Exopalaemon	siberian prawn	79.8		8.3
04GEIS19	4/27/2004	Geis Ditch at Sierra Gun Club MP4	2.9	whole	Corixidae	Water Boatmen	85.4		3

04GEIS20	4/27/2004	Geis Ditch at Sierra Gun Club MP4	2.9	whole	Corixidae	Water Boatmen	89.9		3.1
04GEIS21	4/27/2004	Geis Ditch at Sierra Gun Club MP4	3.6	whole	Corixidae	Water Boatmen	85.6		3
FRCO01	4/27/2004	Fraser Gun Club Brood Pond	4.9	whole	Corixidae	Water Boatmen	88.4		2.3
SCCO01	4/28/2004	Santa Cruz Gun Club Brood Pond	3.8	whole	Corixidae	Water Boatmen	85.6		2.8
SCCO02	4/28/2004	Santa Cruz Gun Club Brood Pond	3.7	whole	Corixidae	Water Boatmen	88		3
SCCO03	4/28/2004	Santa Cruz Gun Club Brood Pond	3	whole	Corixidae	Water Boatmen	86.7		3.1
RFCO01	4/28/2004	Redfern Duck Club Brood Pond	14.2	whole	Corixidae	Water Boatmen	90.4		1.9
RFCO02	4/28/2004	Redfern Duck Club Brood Pond	6.5	whole	Corixidae	Water Boatmen	89.7		1.8
SCAI01	4/28/2004	Santa Cruz Gun Club Brood Pond	8.3	whole	Daphnia	Waterflea	80.1		2.6

APPENDIX 4
OTHER MEDIA

Sample ID	Collect Date	Location/Drainage	Weight grams	Matrix	Genus/Species	Common Name	% Moisture	Se DL Rel	Se Res Dry ppm
04GEIS22	4/27/2004	Geis Ditch at Sierra Gun Club MP4	12	whole	Rana	Bullfrog	85.2		5.8
MARKINW	Spring 2004	Mallard Road at Santa Cruz Gun Club	220.6	Carcass	Lampropeltis	common kingsnake	68.1		2
MARKINL	Spring 2004	Mallard Road at Santa Cruz Gun Club	6.902	Liver	Lampropeltis	common kingsnake	73		3.5
MARKIN	Spring 2005	Mallard Road at Santa Cruz Gun Club	227.5	Whole	Lampropeltis	common kingsnake	-		0.6
GEISSED	4/27/2004	Geis Ditch at Sierra Gun Club	666	top 1"	NA	Sediment	57		1.7
FRSED	4/27/2004	Fraser Gun Club Brood Pond	292	top 1"	NA	Sediment	48	<	0.5
SCSED	4/28/2004	Santa Cruz Gun Club Brood Pond	539	top 1"	NA	Sediment	35.7		0.6
RFSED	4/28/2004	Redfern Club Brood Pond	525	top 1"	NA	Sediment	44.1	<	0.5